Towards a functional definition of "environmental security"

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As demonstrated elsewhere in this volume, it is difficult enough to understand environmental and security issues in the post-Cold War era in their traditional sense given the accelerating rate of comprehensive change we are experiencing at the end of this century. It is doubly difficult, then, to understand what the possible integration of these two policy structures might mean. And yet, there is at least strong intuitive appeal to the possibility that "environmental security," at least in some sense, captures potentially important issues; that is, that the concept, whatever it is called, is substantively valid. Indeed, it is in practice an evolving policy initiative in the United States as well as elsewhere (e.g., Chinese air emissions contributing to acid rain in Japan).

Nonetheless, this is still little agreement on what, if anything, is included or excluded. The boundaries of the concept are indeterminate, and the core is poorly defined. More importantly, the cultural changes in the most relevant communities—environmental, national security, national defense, foreign policy, and related research entities—necessary to move from initial posturing and conflict to integration have yet to occur. An important part of this evolution is to move the discussion wherever possible towards discussion of substantive issues and case studies in the context of an intellectual framework acceptable to all relevant communities (or, as none of the communities are monolithic, a critical mass).

This requires an emphasis on two separate developments. First, it is necessary to reduce some of the ambiguity of the concept by better structuring it. Importantly, this process does not in itself imply there is greater or lesser validity to the concept; it only makes it easier to make that determination in a rational way.

Second, it is important to understand the important role that science and technology (S&T) will play, both by supporting the increased rationalization of the concept, and by developing an S&T capability necessary to carry out the policy in practice. In many cases, such an integrated modeling of relevant natural systems linked from local to regional scale, and short term to long term, will require new research and development (R&D) activities, and access to powerful modeling and computational resources. Part of the challenge of the concept, in fact, is that the necessary S&T even now pushes the boundaries of existing capabilities.

An important result of a better scientific understanding of these issues should be a filter mechanism that can provide at least a conceptual framework to support issue identification and prioritization. Resources, financial and human, are always constrained. Common sense thus dictates the policy principle that, all things equal, investment in relevant science and technology (S&T) should primarily be directed at creating a targeted S&T base to support specific critical elements of an enhanced national security mission, rather than scattered across all potential foreign policy issues, or even potential environmental security issues.

On a final note, cases and discussion in this paper will take the perspective of the United States. This focus aids in exposition, especially given the nascent state of the debate on the concept. Of course, the general principles elucidated below are equally applicable, with appropriate modification of specifics, to other nation-states and perspectives. Also, for ease of exposition, this paper will use the term “environmental security,” although the question of its validity and content is not assumed to be answered.

Components of the enhanced national security mission

Initially, it is important to make the critical point that different policy communities have very different understanding of the term “security.” Most basically, there are two fundamentally different views one can take about environmental security issues. The first, essentially a “global citizen” view, holds that any resource, energy, environmental, or biological perturbation of sufficient magnitude is appropriately considered a security issue, regardless of whether it directly impacts any specific country’s interests (see Figure 4-2 on page 46). Philosophically, this is in keeping with the integrated, regional and global nature of many of these perturbations, such as stratospheric ozone depletion, global climate change, regional, and global distribution of toxics, degradation of air and water resources, and loss of biodiversity (Turner et al. 1990; Graedel and Allenby 1995; Socolow et al. 1995).

On the other hand, the range of issues that potentially arise from a “global citizen” environmental security approach is virtually unlimited, and highly complex, and it is obviously impossible to focus on all of them at once. A filter that limits and prioritizes allocation of resources is a necessity for substantive progress. Moreover, the national policy of the United States, and its implementation by agencies and departments of the federal government, necessarily focus on issues of interest and concern to the citizens of the United States. This leads naturally to a state-centered definition, which may look outward globally, but does so from the perspective of, and reflecting the interests of, the specific state. Even this perspective is, however, not unitary. Some issues may be general humanitarian issues that do not become foreign policy or national security issues (e.g., some famines in Africa). Some may be foreign policy issues, but not involve traditional national security directly (e.g., negotiations over imports of threatened species). Only a few issues and circumstances fit within the category of national security. Even a state-centered focus, however, does not preclude international collaboration; indeed, any successful enhanced national security mission will require such collaboration.

Taking the U. S. focus as a starting point, there is no question that many different perturbations discussed under the general rubric of “environmental security” can, directly or indirectly, cause impacts to the United States. The term is very broad, and includes very different classes of issues that raise quite different operational implications. Accordingly, it is necessary to create a more rigorous framework to support issue prioritization. Attention and resources can then be focused on those impacts that have or well may have substantial security impacts on the country, in the sense that internal stability and/or international authority are challenged, or the probability of conflict, including if necessary military action, to protect the national interest is unacceptably increased.

The Cold War concept of national security was built upon a solid and sophisti-

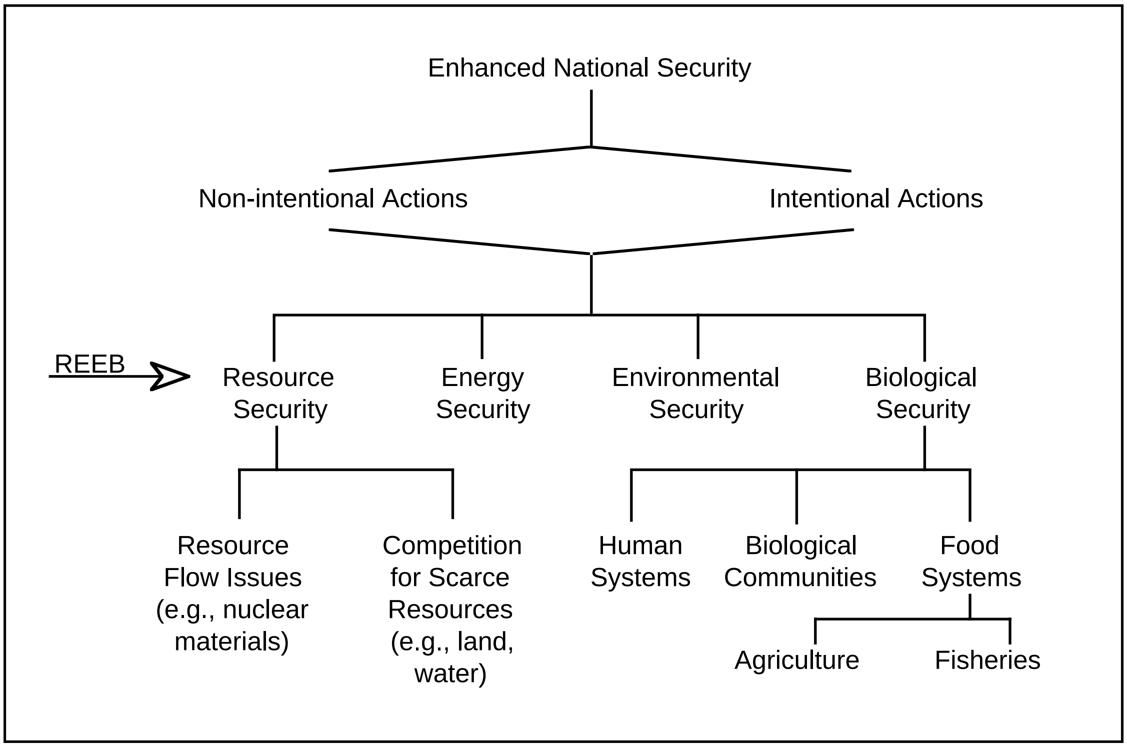

Figure 7-1. Components of the enhanced national security mission.

cated base of scientific and technological understanding, particularly of nuclear technologies. This facilitated rigorous definition, and prioritization, of elements of the national interest, and supported conflict avoidance and minimization efforts even in a highly adversarial environment. Analogously, issues included under the broad term "environmental security" also require a strong underpinning of scientific and technological understanding, a need that has yet to be addressed. In fact, even some of the proponents of the expanded definition may not yet recognize that this need exists.

This understanding, and a more rigorous definition of environmental security, will co-evolve over time. Currently, the term is actually over-broad and potentially misleading. It is thus appropriate to define an analytical framework that supports the evolution of the concept of enhanced national security into operational programs and projects. Viewed from this perspective, the environmental security dimension of the enhanced national security mission is more precisely an amalgam of four conceptually separate components: resource security, energy security, environmental security, and biological security (REEB). Although there is necessarily some overlap among these components, and between them and traditional security concerns, the conceptual separation is instructive (Figure 7-1). Where examples are given, they are illustrative: it is premature without further R&D and definition of the concept to view them as definitive.

1. Resource security involves two subcomponents: 1) local or regional competition for scarce resources, or 2) patterns of resource flows and use. Resource issues in either category become a resource security concern if they have the potential to give rise to political or military conflict of security concern to the United States. Competition for water resources in areas such as the Middle East, or the arid North American West (Liverman and O'Brien 1991; Gleick 1993; Kelly and Homer-Dixon 1995), or arable land in areas such as Chiapas, Mexico (Howard and Homer-Dixon 1995), are examples of competition for scarce resources which may raise security concerns for the U. S. (see also Percival and Homer-Dixon 1995a and 1995b). Managing flows of nuclear materials to avoid proliferation of weapons of mass destruction is an example of a resource security issue arising from patterns of resource flows and use (Center for Strategic and International Studies 1996).

2. Energy security involves the identification and maintenance of access to energy sources necessary to support continuation of U. S. economic and military activities. While military conflict deriving at least in part from competition over secure energy sources has already occurred, public interest in energy security as an issue has waned because many assume that energy security is already assured by existing U. S. policies and military capabilities. Moreover, the desire not to have to deal with energy security as an issue is fostered by the undeniable reality that it would be expensive to maintain a resilient energy posture (reduce energy use per unit Gross Domestic Product (GDP), research and develop alternative production technologies, maintain military preparedness to fight a second Gulf War) (Stagliano 1995).

Nonetheless, it is clear that a stable, sustainable, and affordable flow of energy is critical to all developed economies: in the United States, for example, energy fuel and services account for almost 10% of GDP, with derived benefits estimated to be more than half of the nation's GDP. Energy markets are, however, increasingly unstable, and thus energy security must be regarded as an increasing concern, especially as competition for available traditional energy sources grows more intense as global economic activity accelerates. Growth in demand, particularly in Asia, clearly threatens existing reasonable prices for, and access to, energy derived from various sources, particularly petroleum (Calder 1996; Romm and Curtis 1996).

Several points regarding energy security are worth noting. First, as with resources, absolute scarcity of potential energy resources is unlikely to be a concern; rather, rapid fluctuations in supply and demand, local and regional scarcities, and the long lag times required to shift among different energy production and consumption technologies, are the potential problem. Environmental and other social costs associated with energy production may also rise significantly as global energy markets expand substantially. Examples include greater frequency and amount of petroleum spills; increased leakage of natural gas from production, transportation, and storage facilities; and costs associated with management of nuclear power residual streams (the Yucca Mountain nuclear materials storage facility project in the United States has already cost some $1.7 billion [Whipple 1996]).

Additionally, because energy is among the most critical inputs into any developed economy, U.S. security can be threatened in two ways by even temporary energy shortages. The most obvious is directly (a scarcity domestically); equally important, however, is the potential for indirect significant impacts, as the economies of foreign trading partners are adversely affected. The U. S. economy is now so linked to the global economy that a significant perturbation to the latter could easily generate a recession, if not depression, in the United States, and at the least would be politically difficult domestically.

3. Environmental security involves the maintenance of environmental systems whose disruption would likely create national security concerns for the United States. Such issues could arise in either a domestic or foreign context. Examples might include releases of nuclear material in one state that, over either the short or long term, generate substantial impacts on other states (Bradley et al. 1996), or environmental degradation in one locality that are so intense as to generate substantial population migration or other conditions with the potential to create conflict situations of concern to the United States (cf. Gizewski and Homer-Dixon 1996). Thus, for example, environmental degradation in the former Soviet Union (FSU) has been identified by a number of experts as an important contributing factor to greatly increased migration throughout the region, which may generate possible political and military consequences (Feshbach, 1995).

4. Biological security involves maintaining the health and stability of critical biological systems whose disruption would likely create national security implications for the United States. Such systems could be either domestic or foreign. The two most obvious classes of systems are 1) human populations, and 2) food systems, including crops, livestock, and fisheries. A third, less obvious class of systems is biological communities of various kinds, such as wetlands, forests, or critical habitat, which frequently provide important "natural infrastructure" functions, such as flood control or fisheries breeding areas. A particularly difficult set of issues in this latter class arises when activity in one country affects an internal biological community, whose disruption has extraterritorial effects.

A domestic example of a biological security incident would be the release, either deliberate or as a result of changing climate patterns, of a pathogen that attacked a major food crop. A foreign example that combines resource security with biological security would be changes in precipitation patterns in China that disrupted water supplies (a resource issue), which in turn resulted in significant negative impacts on crop success, thereby generating both economic disruption as China accessed world markets in response, and potential conflict situations if strong pressure for population migration were created. An example of the third class would be when deforestation of the upper reaches of a watershed for a major river reduced the ability of that biological community to absorb and retard stormwater, generating unprecedented flooding in downstream nations (as with India and Bangladesh).

A potential biological security issue worth noting involves potential change in pathogen activity and distribution. Increased pathogen exposure and virulence due to changing cultural patterns (e.g., global travel), rapid evolution of bacterial resistance to antibiotics, and changing climate and human settlement patterns has been an increasing concern among experts (Pirages 1996). It is generally not realized how many previously unidentified infectious agents are still being detected. Since 1982, for example, 11 human diseases have been newly identified, including human immunodeficiency virus, hepatitis E virus, hepatitis C virus, Venezuelan hemorrhagic fever, Brazilian hemorrhagic fever, human herpesvirus 8 (Keposi's sarcoma), and HTLV-II virus (hairy cell leukemia). The possibility of significant domestic impact on human or biological system health as a result of new pathogen activity is, indeed, one that cannot be ignored. It remains true, however, that the 10 infectious diseases causing the most fatalities, with the exception of HIV/AIDS, tend to be clustered in developing countries (acute respiratory infections, 4.4 million deaths in 1995; tuberculosis, 3.1 million; diarrheal diseases, 3.1 million; malaria, 2.1 million; hepatitis B, 1.1 million; HIV and measles, greater than 1 million each; neonatal tetanus, .5 million; whooping cough, .335 million; and roundworm and hookworm, .165 million (data from *Science*, 31 May 1996, p. 1269)).

The potential for significant national impact from altered pathogen behavior and distribution is thus apparent, although immediate threat is less obvious, as is the appropriate role for traditional security-oriented organizations. This suggests that implementation of a balanced research program, with specific attention paid to the pathogens which might pose a threat to the United States, along with the conditions, existing or foreseeable, under which they might do so, would be an advisable course of action, offering efficient resiliency of response—but that traditional response agencies such as the Centers for Disease Control and the National Institutes of Health, rather than the national security apparatus, are the appropriate vehicles for such a response.

Intentional and unintentional perturbations

A second classification of potential REEB perturbations, differentiating between intentional and nonintentional activities, is useful in constructing an enhanced national security structure. Both intentional and nonintentional activities must be considered as part of an enhanced national security mission, but there is an important distinction. Nonintentional activities may or may not rise to the level of resource, energy, environmental, or biological security issues. Intentional ones, on the other hand, frequently will, as they are, by definition, extensions of another state's policies and interests through deliberately chosen actions. Moreover, they are more likely to be difficult to counter, and more likely to constitute a significant threat, as they presumably have been chosen to be effective.

The ability to generate such threats is augmented by the characteristics of the natural systems upon which they are based: local actions can frequently perturb regional or global systems, thus permitting a state to project international threats based on internal activities. The Chernobyl incident is an unintentional example that involved only one facility but affected much of Europe (Shcherbak 1996). Moreover, because of the technically complex nature of such systems, a relatively simple perturbation can have numerous and complex potential effects that are virtually impossible to counter once the system is perturbed.

In some cases, however, particularly where conflict has already begun, the distinction between the two may be difficult and ultimately not meaningful. For example, a concern arose during the recent Gulf War that the Iraqis would burn so much oil that the resultant particulates would lower global temperatures and sunlight penetration, creating a widespread ecological disaster. Rapid assessment by the U. S. Department of Energy national security laboratories indicated that such a threat was groundless, but, had such an S&T assessment capability not been available, the impact on planned military initiatives in the area might have been substantial. Moreover, even though the larger threat was groundless, the environmental conditions that were created during the conflict by the intentional burning of petroleum by Iraqi forces generated difficult military and personnel conditions, and the possibility that the health of U. S. and allied troops was affected is still under investigation. Under these circumstances, the intent of the Iraqis is relatively unimportant.

Structuring an enhanced national security mission

The Cold War national security policy structure consisted of two closely linked primary components: an S&T base that provided military capability, threat definition, and technological support for collaborative threat reduction (e.g., monitoring treaty compliance); and a policy component supported by that base. The structure required to support an enhanced national security mission is analogous, but perhaps not as widely recognized. In particular, it is necessary to build an S&T capability to support the development of the resource, energy, biological, and environmental components of national security.

Figure 7-2 illustrates the policy/S&T framework for an enhanced national security mission. The first step in creating the S&T base for a particular issue is to understand the dynamics of the underlying physical system, which might include, for example, generating a model of its behavior. Depending on the system, such models may be fairly simple (as, perhaps, where resource competition involves land allocation that is more a matter of culture, history and politics than the underlying characteristics of the land itself, as in Chiapas, Mexico, where the Zapatista National Liberation Army is challenging the state). On the other hand, they might be quite complex, as where, for

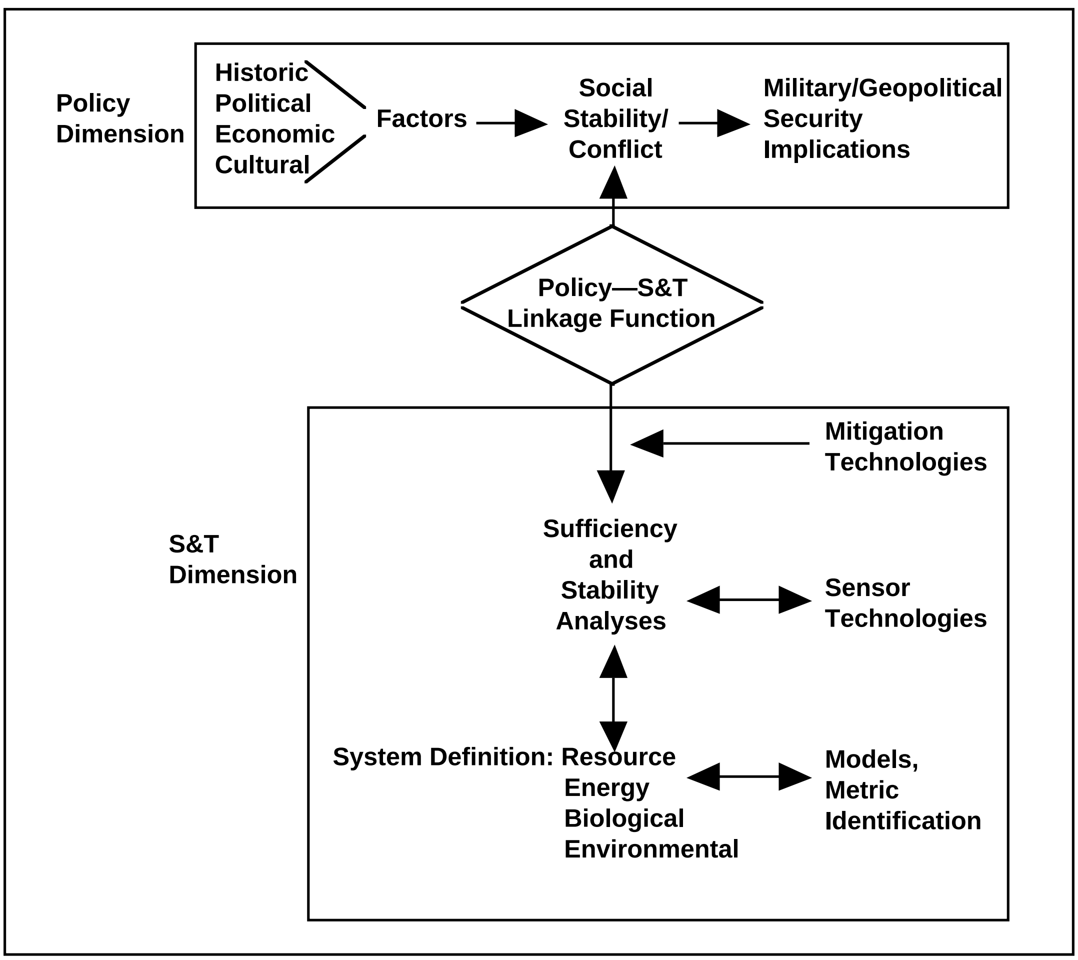

Figure 7-2. Enhanced national security policy structure.

example, an attempt to understand potential future precipitation patterns and water management systems in Asia would be part of a confidence building program with the goal of ensuring that crop failures and food shortages did not result in destabilizing population migrations. Such a model might have to link together a number of sub-models covering a wide spatial and temporal scale.

As understanding of the system is gained, metrics by which one can evaluate its evolution over time can be developed. Ideally, such metrics will support the ability to predict when the system might be approaching instability, a particularly important concern since patterns of human activity tend to be predicated on the assumed stability of underlying natural systems, and much human effort is essentially aimed at engineering such stability in inherently variable systems. Thus, for example, much of the manipulation of rivers in the Middle East is intended to stabilize their annual supply of water at the highest possible level (these riverine systems are by nature highly unstable), as well as to expropriate as much of the resource as possible. Instabilities in natural systems, such as precipitation patterns, changes in groundwater flow, or other perturbations that either increase the interannual variability, or reduce the amount of water that can be reliably produced, can under the circumstances generate the potential for resource scarcity conflict.

Once the system is defined and its behavior and stability assessed, sensor technology to provide input and track system evolution against the appropriate metrics can be deployed. Depending on the parameter, sensor systems may be either ground- or satellite-based. A great deal of sensor technology has been developed for military applications and is resident in the national laboratories, and the opportunities to apply such technology to enhanced national security issues is both substantial and largely unexplored.

Finally, understanding the physical systems relevant to a possible security issue provides an opportunity for development of mitigation technologies, including if appropriate traditional remediation technologies, before the potential conflict develops. In fact, with luck the issue can be identified, defined, and resolved within the context of a collaborative S&T effort without rising to the policy dimension at all. For example, if crop failure resulting from changes in precipitation patterns is a concern, an entire set of mitigation efforts is possible, depending on the time scale. With several years warning, new crops and cultivars that are more robust under the predicted conditions can be introduced. Even with less warning, water recycling, demand reduction, and water storage technologies can be deployed. At the least, appropriate food transportation, storage, and distribution facilities can be prepared. Additionally, of course, a number of mitigating policies can be adopted by the international community based on the projected perturbation, including, for example, more planting of grain in other exporting countries to buffer the anticipated demand.

Once the S&T dimension of a particular issue or set of issues is established, it is then possible to integrate the results into a robust security analysis and policy. While it is possible that a natural system perturbation, in itself, could generate national security implications, it is more likely that in many cases the national security effects of perturbations will arise only when they occur in conjunction with more traditional indicia of state instability, which themselves reflect specific historic, political, economic and cultural factors. Thus, the S&T base does not replace, but is a necessary component of, enhanced national security policy considerations and analyses.

Experience indicates that the linkage between the S&T and policy dimensions, while conceptually apparent, is frequently weak or less effectual than possible. This might be particularly difficult as the organization providing the S&T capability will in most cases not be the organization making the policy decisions. It is therefore worth emphasizing the need to establish a clear linkage function between the S&T and policy dimensions, as shown in Figure 7-2, at the outset.

Like any effort to change existing institutions—in this case, by integrating environment with existing policy and organizational systems—it is highly desirable to minimize the degree of change to that which is absolutely necessary, and to draw on existing structures to the extent possible. It is likely that the challenges of an enhanced national security mission will, over time, call forth new organizations with the broad, multidisciplinary mandates implied by the complexity and cross-cutting nature of such a mission. In the short term, however, it is easier and less confrontational if the organizational structure for an enhanced national security mission tracks that already existing, with appropriate enhancements to reflect the extension of the mission.

This process has begun in the United States, with the Department of State taking the lead, and, based on a Memorandum of Understanding signed in 1996 by the U. S. Environmental Protection Agency, the Department of Energy, and the Department of Defense, support being provided by other entities. The complex nature of the potential threat in this case, however, suggests that once a robust support structure for REEB issues is in place, it will require the collaboration of a number of departments and agencies, including, for example, the Department of Agriculture, NASA, the Department of Commerce, and the Department of the Interior. Moreover, in the vast majority of cases, the foreign counterparts of these agencies, as well as international agencies such as NATO, should also be included in the collaborative effort to address these issues as appropriate.

An important part of the cultural change implied in the process of integrating environment with other policy and organizational structures is ensuring that meaningful authority relationships are established within institutions. It is not enough to simply start a new “Office of Environmental Security” or the equivalent. Rather, it is necessary to ensure explicit ownership of the program by an appropriate, and appropriately powerful, office within each participating agency. The scope of the office should be both broad enough to allow it to manage the program as a whole, and important enough organizationally to ensure that REEB hasn’t been just superficially adopted, but effectively sidelined, by the bureaucracy (as some have argued has happened to some extent in the U. S. Departments of State and Energy).

It is also important to note that institutionalization of the enhanced national security mission will require establishing new collaborations, not just among U. S. departments and agencies, but with both friendly and potentially competitive states, a program that can build on much existing work, but in many cases will go beyond it. Here, also, the difference between intentional and nonintentional REEB events is important: collaboration will undoubtedly be more difficult in the former than in the latter case. Most difficult, perhaps, may be those issues, such as nuclear material management, that cut across both military and traditional security (e.g., nonproliferation and nuclear smuggling concerns), and REEB, civilian-oriented, enhanced security (e.g., nuclear energy production) arenas.

Prioritization of enhanced national security issues

The most important initial focus of the enhanced national security mission will be on existing or foreseeable intentional threats, and on those nonintentional issues that have already given rise, or contributed to, national security concerns. An example of the latter is provided by the well-known issue of water quality, and water reallocation, in the Middle East peace process (Kelley and Homer-Dixon 1995). Another example is North Korea, where nuclear material stocks and flows are of significant proliferation concern, and (alleged) food shortages resulting from unusual precipitation patterns and flooding, may be creating destabilizing conditions that, given the posture of the state, may lead directly to initiation of military conflict.

These conditions, which almost by definition are giving rise to current national security concerns, must be addressed on an immediate basis. The value added to them, however, by the REEB approach is to offer a framework within which enhanced understanding of the underlying physical systems, and perhaps technology development and deployment efforts, can be developed as a part of existing policy initiatives to reduce tensions and avoid escalation of conflict. Response to the North Korean situation, for example, has already included transfer of energy production technology designed to increase that state's energy security. Response to the food shortage issue might include not just the immediate response—provide food—but development and deployment of a more sophisticated conflict avoidance S&T strategy, to include developing models and sensor systems (probably satellite based, under the circumstances) that can help predict when perturbations in underlying physical systems could impact food production and distribution.

The real advantage of the REEB approach, of course, is in its ability to reduce the possibility, severity, and expense of future national security impacts and conflict. If this promise is to be achieved, the purpose of the REEB enhanced security mission must be kept in mind. The enhanced national security mission is not intended to cover all identifiable perturbations, or even the full universe of foreseeable impacts of REEB perturbations on the United States or its citizens. Rather, it is to support a prioritized approach to those regions and issues that, at least initially, appear to offer the greatest potential impacts on the security of the United States.

One can identify several prioritization mechanisms to be used in tandem. It is apparent that some regions are more critical to U. S. national security than others. Moreover, some issues will be of more importance to the United States than others: nuclear material flows, for example, will be a consistent resource concern globally. Finally, traditional indicia of environmental impacts—including the duration, severity, and geographical scope of the insult, and the technical difficulty and expense of mitigation—will also be important in prioritizing enhanced national security issues.

Application of these prioritization mechanisms to the set of potential issues cannot be done rigorously a priori. It is possible, however, to construct a matrix using these guidelines (Table 7-1) that links five geographic areas of self-evident critical geopolitical interest to the United States—China, Mexico, the former Soviet Union, Southeast Asia (including India and Pakistan), and the Middle East—with the four REEB categories. Where applicable, within each cell examples of issues that would appear to

Table 7-1. Possible initial focuses for enhanced national security initiatives.

	Resource Security	Energy Security	Environmental Security	Biological Security
China	•nuclear materials •commodity consumption patterns •water	•petroleum demand •petroleum supply •nuclear energy systems	•environmental costs of economic growth	•crop stability and food demand growth •population stability
Mexico	•water •land distribution		•environmental costs of economic growth	•crop stability •pathogen systems •population stability
Fomer Soviet Union	•nuclear materials	•nuclear energy production technology	•environmental costs of economic growth •nuclear waste issues	•population stability
South East Asia	•nuclear materials •water	•petroleum demand •petroleum supply •nuclear energy systems		•de-mining •crop stability and food demand growth
Middle East	•nuclear materials •water	•petroleum supply		

be the most pressing are identified. Similar matrices could easily be generated by other countries as well.

While this structure should not be interpreted to imply that other geographical areas, or REEB issues, are not of concern, significant instability in any of these regions could have immediate and serious foreign policy implications for the United States. The mechanisms by which REEB forcing functions might impact states may vary— population migration, increased state instability—and the effects on the United States could be either direct (e.g., increase in NAFTA population migration, or diversion of nuclear material to terrorist organizations) or indirect (e.g., instability in Asia or China causes regional economic dislocation, which in turn generates recession or depression in the United States). Nonetheless, the potential impacts of these particular issues on the United States and its citizens are, by-and-large, both apparent and potentially significant. To illustrate this point more specifically, two initial case studies can be suggested.

Case study number one: water and food in Mexico

Global population migration, both internal and external to existing states, is a continuous and probably inevitable phenomenon. In most cases, it will not raise national security issues for the United States, although it may call for humanitarian foreign policy responses. There are a relatively few cases, however, where such migrations may have such direct impacts on the United States as to give rise to legitimate national security concerns.

One class of events that can give rise to such migrations is perturbations to natural systems that, in conjunction with state resource management regimes, give rise to crop failure and food shortages, and hence discontinuous increases in migration from affected rural areas. Thus, for example, a change in precipitation patterns (flood or drought), or failure of irrigation sources because of aquifer drawdown, combined with inadequate planning or state response, might generate substantial migration pressures that could prove internally destabilizing or generate external conflict. The two states where such a pattern could most obviously raise enhanced national security concerns for the United States are Mexico and China, with other situations arising for unique reasons (e.g., North Korea crop failure generating pressure on the state to initiate foreign adventurism). The case of Mexico will be used as an illustration of this class of conditions.

Mexico is currently undergoing rapid economic and political evolution as it adjusts to the accelerated regionalization of its economy, partially as a result of the North American Free Trade Agreement, and concomitant political evolution away from the paternalistic one-party system that has characterized its governmental structure since World War II. Peasant technologies little changed for centuries, especially in the agricultural sector, coexist with modern industrialized facilities owned by transnationals competing in global markets. Cultural and legal systems that embed traditional class structures and support land-owning elites are increasingly challenged by modernist reformers, a conflict that in Chiapas led to armed confrontation between the Zapatistas and the state (for a discussion of the relationship between water and land resources, and the Zapatista rebellion, see Howard and Homer-Dixon 1995). Under these already somewhat unstable circumstances, crop failure as a result of water quality and/or quantity limitations may be a trigger for substantially increased internal unrest and consequent migration.

The national security threat implicit in this situation is twofold. Most obviously, the disparity in economic conditions between many areas in Mexico, and the wealthier districts in Mexico and the United States, has generated substantial migration, both internal, and between the United States and Mexico. The latter has already led to political conflict within affected U.S. jurisdictions (e.g., Proposition 187 in California restricting availability of public services such as school for illegal migrants, reflecting a widespread backlash in that state against migration from Mexico), and between the U.S. and Mexico. Violent incidents arising from efforts to restrict illegal immigration, including one involving alleged beatings of such migrants by law officers, are on the increase. Political reactions in the U.S. involve increased xenophobia, increased social tension, especially in border areas in California, and efforts to impose restrictions on migrants that have the effect of encouraging discrimination against American citizens of Hispanic descent.

Second, NAFTA is both a continuation, and a recognition, of a trend towards a regionally integrated economy including Canada, the United States, and Mexico (and perhaps others such as Chile). Disruption of these growing economic relationships would be costly both politically and economically, and would have the potential to generate a negative feedback loop: increased economic hardship in Mexico would lead to increased migration pressure, which, in turn, would exacerbate the political and economic disruption of existing NAFTA arrangements.

In both cases, an important forcing function for destabilization in an already difficult situation (e.g., a weakened state in a period of economic and political transition), and consequent migration, would appear to be perturbations to available water resources. Policies that more rigorously define, and concomitantly provide the basis for reducing, that forcing function are therefore desirable, all else equal. As in Figure 7-2, these policies will fall into two dimensions: the familiar policy dimension, and the less familiar S&T dimension.

More specifically, what S&T base should be developed to help support the stability of existing population patterns in Mexico and the border areas of the United States? The following discussion, as summed up in Figure 7-3, is suggested as illustrative: it is not definitive because, of course, a full initial assessment has not been done, and development of such a base will be iterative in practice. It is also important to confirm ab initio the obvious point such an S&T research program must be a fully collaborative effort with Mexico.

1. A key driver for population migration is agricultural failure, either real or perceived (that is, urban or United States life being perceived as increasingly desirable compared to the rural alternative). This in turn generally arises from patterns of distribution of two key resources—water and land—given existing populations and expectations. The linkage between the S&T dimension and the policy dimension thus flows through these categories. Both dimensions must be understood if the national security concerns are to be mitigated.

2. The S&T research program begins with development of a set of models that can be used to identify geographical and technological areas of greatest concern (e.g., where are resource conditions most marginal to begin with, and is there a crop or set of crops which are least stable under prevailing conditions?). Such a system might begin by looking at existing precipitation patterns at a relatively high level with a global or, more likely, mesoscale model. Then, a set of subsystem models of crop distribution and response, soil systems (the pedosphere), localized precipitation patterns, runoff and watershed response, and groundwater systems would be used to link precipitation with ability to support current agricultural systems, and determine whether, and to what extent, instability in precipitation patterns could generate meaningful agricultural disruption (i.e., disruption that would be significant enough to generate substantial pressures for migration or other potential impacts). Throughout this process, uncertainties of all kinds that might impact the prediction should be identified.

3. Once the baseline systems, including modeling and data components, are in place, a predictive capability would be built. The essence of this activity would be to identify potential instabilities in resource availability before they occur, determine whether they would be meaningful if they occurred, and identify uncertainties associated with the prediction (some of which, like poor data, might be reduced by further research, while some, such as chaotic behavior of natural systems, might be irreducible within certain boundaries). For example, is it possible to tell from an integrated assessment of data and models when Mexican precipitation patterns in key areas are becoming unstable in such a way as to impact critical agricultural activities before the fact? As Figure 7-3 indicates, answering such questions involves integrating models of many different kinds, which may operate over very different spatial and temporal dimensions. This is a nontrivial challenge, and may not be possible, at least at first, beyond one or two years, but it is an important step to support the development of mitigation technologies.

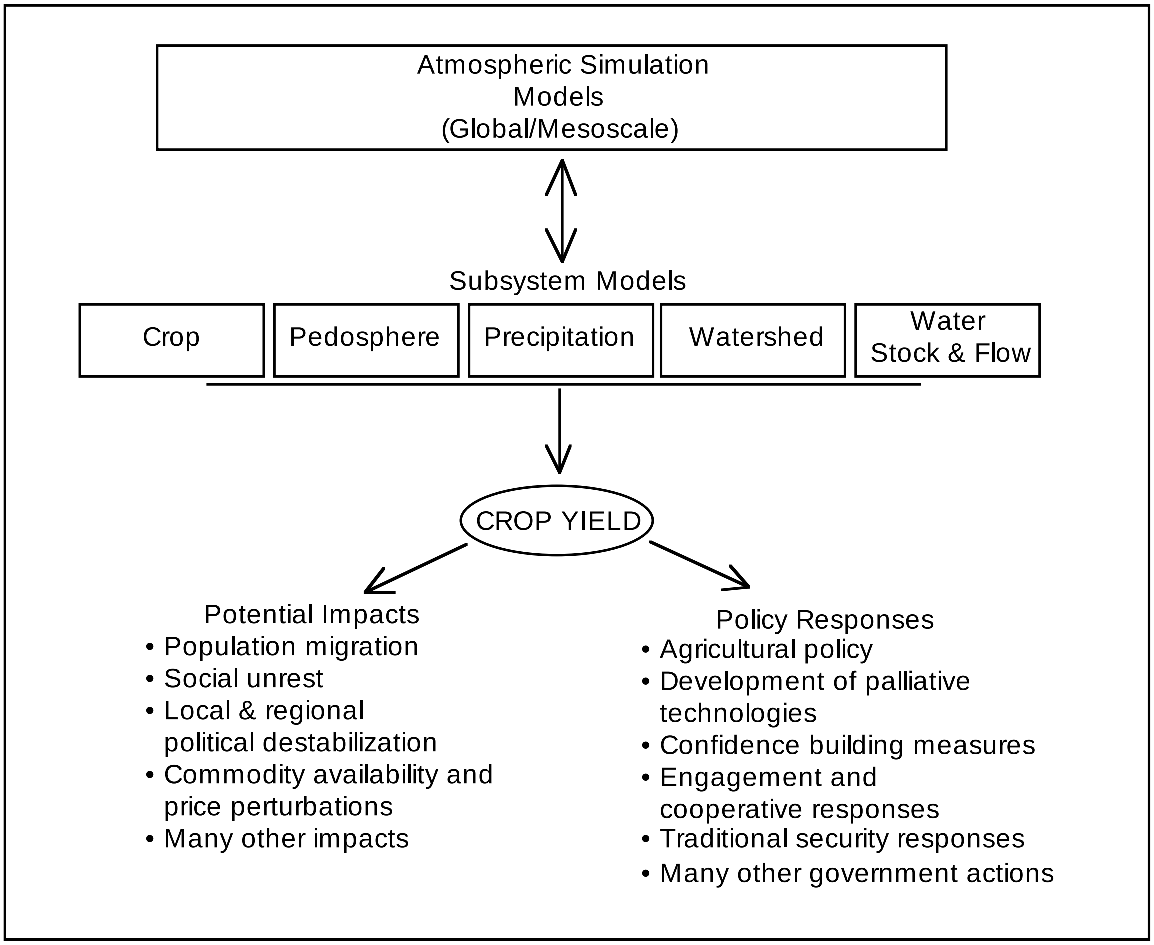

Figure 7-3. Building a science and technology base: water/food case study.

4. Concomitant with S&T system development and deployment is the need to deploy the appropriate sensor systems to monitor the physical system's state and performance. One might, for example, need data not just on precipitation and surface water flows, but on soil moisture content, vegetation stress, nutrient availability, and other parameters. Such sensor systems would probably include a satellite-based component, but, as always, ground-based verification of satellite data, and independent data generation regarding parameters that cannot be determined by remote sensing technologies, would be desirable.

5. The final step would be to develop and deploy mitigating technologies, which could range from engineering new varieties of existing crops, to introduction of new species entirely, to water or resource recycling or replenishment technologies. This step in particular must be linked to policy and state initiatives, as technology is a cultural as well as an engineering phenomenon, and inappropriate technologies may be perfectly apt, but are unlikely to be successfully deployed. Additionally, the economic dimensions of such shifts in technology may be complex in themselves. Again, collaborative effort is an obvious key to success.

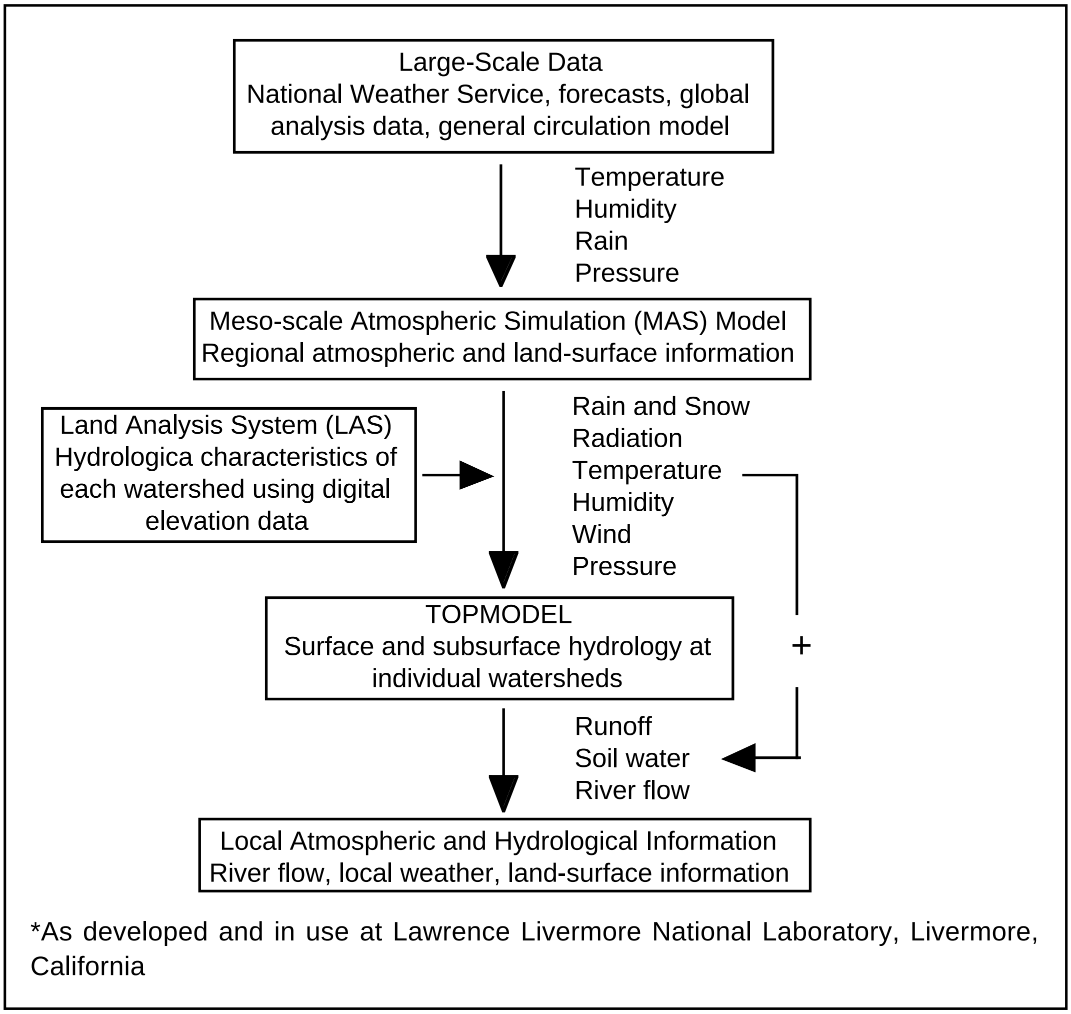

Figure 7-4. Coupled atmosphere-riverflow simulation system.*

The S&T set of activities would both inform, and be taken concomitantly with, appropriate policy initiatives. Ideally, they will permit the development of an increasingly sophisticated capability for collaboration and conflict avoidance, a particularly important issue in this case study, where the U.S. national interest in a secure and stable southern border is obvious. It is worth noting that such integrated models are currently being developed for a number of uses; Figure 7-4 is a schematic of an integrated coupled atmosphere-riverflow simulation model developed at Lawrence Livermore National Laboratory to help manage regional water systems.

Case study number two: nuclear materials

Nuclear materials are an example of a resource security issue that cuts across both traditional and enhanced national security interests, and includes significant energy security and biological security dimensions. Their inherent characteristics, uses, management, and impacts as improperly handled waste raise some of the most difficult and complex issues in the modern world. They are the basis for nuclear weapons, which previously were reserved to a limited number of states, but are now potentially available to terrorist organizations. They also are the basis for nuclear power, a technology which almost certainly will be increasingly deployed in the future, especially in Asia where economic expansion is driving an almost desperate increase in demand for energy production. The science and technology surrounding them in virtually any application is complex and arcane (Figure 7-5 provides a high level overview of nuclear materials flow), while the politics are polarized and bitter, whether the use is military or civilian.

Nuclear waste, whether in the United States, the FSU, or, increasingly, in Asia, potentially poses some of the most serious real risks associated with environmental pollution, and cleanups are both expensive and technically challenging—where they can be done at all (Bradley et al. 1996). Some contamination incidents—Chernobyl being the classic case—have caused extensive regional contamination which, had it not obviously been unintentional, might in itself have been a trigger for conflict. Even though unintentional, the impacts were enormous: within the Ukraine alone, 135,000 people were displaced within 10 days as a direct result of the incident, a figure that has since grown, and over 5% of that state's area remains significantly contaminated (Shcherbak 1996). The continuing destabilizing effects of that incident are demonstrated by the fact that, even now, the Ukrainian government, in a severe economic crisis, must continue to spend more than 5 percent of its budget in dealing with the continuing impacts of Chernobyl, including, for example, providing emergency housing to over 3 million directly affected people in Ukraine alone.

Dealing with nuclear materials issues is difficult in part because of their military (and terrorism) implications: civilian stocks and flows of such materials are linked inevitably with military and security concerns, and the potential for "environmental terrorism": a terrorist group would not need to explode a weapon, but could simply distribute radioactive materials widely in a heavily populated area, to achieve an impact (Center for Strategic and International Studies 1996).

Of course, a number of scientific, technical, and political efforts have been made to reduce the various risks that nuclear materials pose in various military and civilian applications, and a number of national and international organizations, including the International Atomic Energy Agency (IAEA) are active in supporting that goal as well. Nonetheless, the effectiveness of such efforts is limited by activities of rogue states (e.g., North Korea, Iraq), and a lack of resources (e.g., to provide alternative energy production sources to replace allegedly unsafe reactors, or support IAEA activities at a sufficiently high level).

More fundamentally, increases in nuclear power production are projected, especially in Asia; Table 7-2 shows that as of 1993 there were 441 units operating globally, with another 86 planned. These 1993 figures understate those that are now contemplated by developing countries such as China, which currently has 14 new units either planned or under construction, but probably overstate those planned in the former Soviet Union (FSU), thus demonstrating the volatility of such projections (see DOE EIA 1996, pp. 57-64, for a recent summary of current nuclear power capacity projections). When combined with a lack of knowledge about the nuclear materials system as a whole, these trends clearly indicate a potentially substantial increase in future national security risks associated with global nuclear materials management.

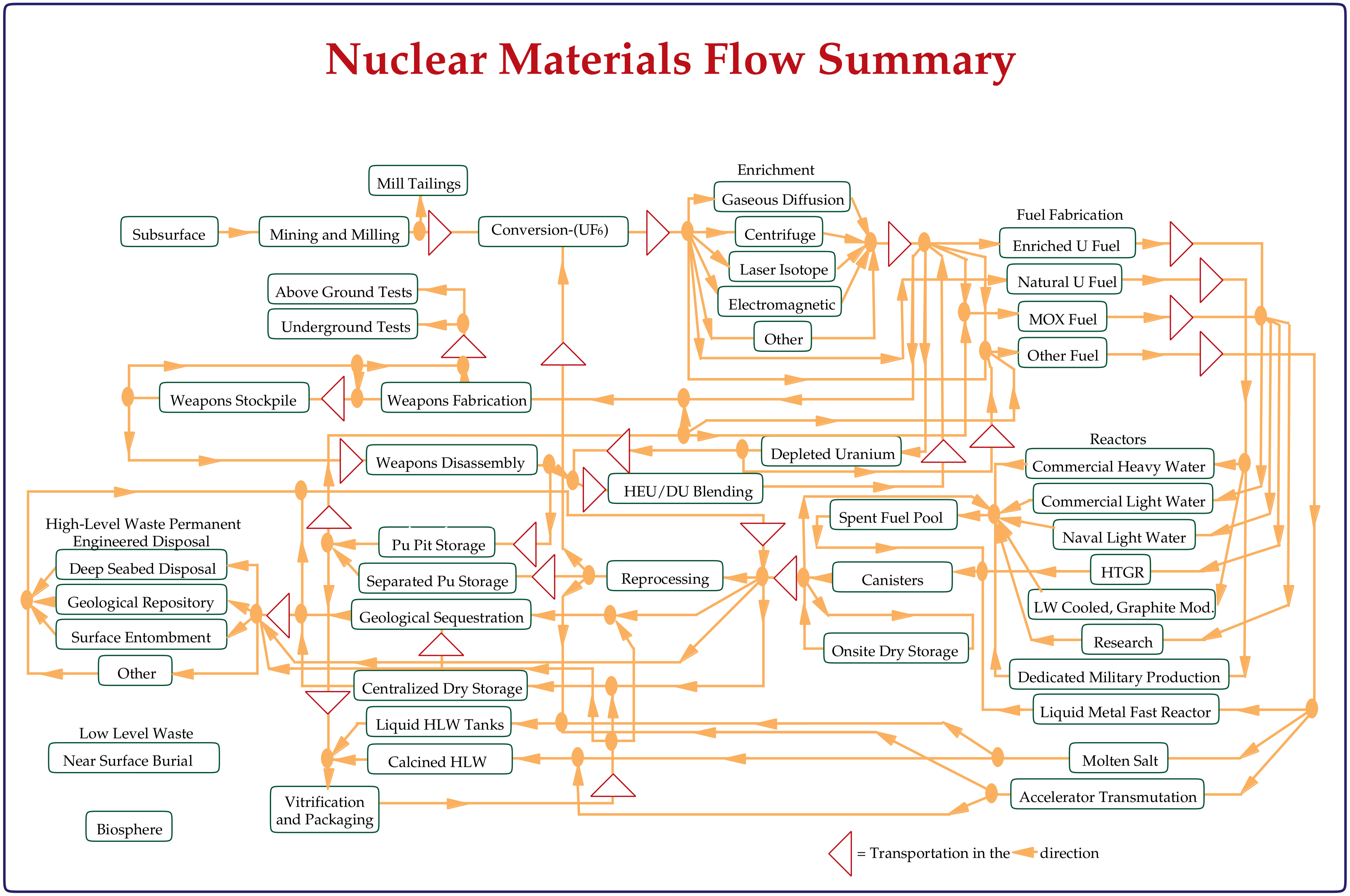

Figure 7-5. Nuclear materials flow summary.

Table 7-2. Reactors: operable, under construction, and planned (1993).

	Operable		Under Construction		Planned		Nuclear Generation in 1992	
	Units	MWe	Units	MWe	Units	MWe	TWh	% of Total
Agentina	2	1005	1	745	0	0	7.08	14.8
Bangladesh	0	0	0	0	1	300	-	-
Belgium	7	5834	0	0	0	0	40.09	59.9
Brazil	1	657	1	1309	0	0	1.75	0.8
Bulgaria	6	3760	0	0	0	0	11.5	32.5
Canada	22	16393	0	0	1	450	81.78	16.4
China, Peoples Rep	2	1284	3	2184	5	0	-	-
Czech Repulbic	4	1728	2	2000	0	0	12.25	20.7
Egypt	0	0	0	0	2	2000	-	-
Finland	4	2400	0	0	0	0	18.2	28.9
France	58	61899	3	4548	7	10150	321.7	72.8
Germany	20	22426	0	0	0	0	158.8	34
Hungary	4	1840	0	0	0	0	13.98	44.6
India	10	1733	8	2100	8	2880	6.33	2.1
Israel	0	0	0	0	1	950	-	-
Japan	48	38541	7	6925	15	16195	214	34.7
Kazakhstan	1	150	0	0	0	0	-	-
Korea, Rep of	9	7624	7	6079	7	6700	56.53	43.2
Lithuania	2	3000	0	0	0	0	14.64	78.2
Mexico	1	675	1	675	0	0	3.92	3.2
The Netherlands	2	539	0	0	0	0	3.21	5.4
Pakistan	1	137	1	310	0	0	0.55	1.2
Romania	0	0	5	3530	0	0	-	-
Russia	39	21926	3	3000	35	26496	119.6	11.8
South Africa, Rep of	2	1930	0	0	0	0	9.29	6.2
Slovakia	4	1760	4	1760	-	-	11.05	49.5
Slovenia	1	664	0	0	0	0	3.77	20.9
Spain	9	7400	0	0	0	0	55.73	35.5
Sweden	12	10158	0	0	0	0	61.0	43.3
Switzerland	5	3141	0	0	0	0	22.23	38.7
Taiwan	6	5144	0	0	2	2000	32.5	25.7
Turkey	0	0	0	0	0	0	-	-
Ukraine	14	12808	3	3000	0	0	73.75	29.4
UK	35	13063	1	1258	2	2600	48.44	18.1
USA	110	105055	5	6212	0	0	606.3	21.7
TOTAL	441	354674	57	45635	86	74521	2009.69	

An alternative scenario, however, based on the obvious recognition that safe global management of such materials is an important component of U.S. national security, would develop and deploy an S&T strategy that would both reduce risks, and, in many cases, provide an important vehicle for developing collaborative and confidence building exercises with other states (an important goal given that many of these states are either actually or potentially nuclear powers). Such a program would consist of several major components.

1. Construction and maintenance of a global data base and model system capturing the stocks and flows of as much nuclear material as possible. Such a system should be driven by a need to understand the physical structure of the "industrial metabolism" of these materials, not by, for example, relatively arbitrary regulatory distinctions between different kinds of "wastes", or regulatory regimes. It should be as complete and transparent as possible, recognizing that, at the margin, military security concerns will undoubtedly arise.

2. Development and deployment of sensor and materials security systems globally that can help assure the integrity of nuclear material storage and management, and prevent theft or diversion into informal channels.

3. Sponsorship of regular technology transfer activities, whereby global nuclear operations, particularly nuclear power and fuel cycle activities, can all be raised to world class safety and risk reduction levels.

Conclusion

This paper has attempted to provide more rigor to nascent efforts to integrate environmental issues and national security structures, a policy evolution that reflects the increased complexity and challenge of both anthropogenic environmental perturbations and the post Cold War geopolitical environment. It thus proposes a more rigorous definition of the components of the enhanced national security mission—resource security, energy security, environmental security, and biological security—as well as suggesting a more targeted approach to identifying the circumstances under which U.S. national security is actually at issue. Two case studies, one involving collaboration with a neighboring state, and one involving global resource security issues, are used as illustrative case studies.

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